theory if time is allowed for them. The change at the G temperature is the breaking up of a solid solution into a mixture of the compound $Cu_3Sn$ and liquid, and is instantaneous: here we have a case of a solid partially melting as it cools.

The curve lXE′*f* forms with the part of the solidus immediately above it an area, roughly triangular, within which all the alloys appear to be uniform solid solutions, but, as soon as an alloy cools to the curve, it becomes saturated and a new body crystallises out of the solid solution. One branch of the curve lXE′*f* corresponds to the crystallisation of a body rich in copper, the other to the crystallisation of a body rich in tin, which is probably the pure compound $Cu_4Sn$. The angle X (or rather C′), is the eutectic angle at which both bodies crystallise together, the whole phenomenon being exactly like crystallisation out of a liquid.

All the results obtained from the study of the chilled alloys are in harmony with the pyrometric work of Roberts-Austen and Stansfield, and many of the changes we have examined correspond to an evolution of heat recorded by them.

The paper is an extension of a short paper published by us in the 'Proceedings' of December, 1901.

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## "On the Formation of Barrier Reefs and of the Different Types of Atolls." By Alexander Agassiz, For. Mem. R.S. Received February 7,—Read March 19, 1903.

The results here presented are based upon observations carried on during the past 25 years in Florida, the Bermudas, Bahamas, Cuba, Jamaica, and the West Indies in the Atlantic. They include in the Pacific the Galapagos, the Hawaiian Islands, the Great Barrier Reef of Australia, the Fiji Islands, and the Coral Reefs and Islands of the tropical Pacific, from the Marquesas to the Paumotus, the Society Islands, the Cook Archipelago, Niue, the Tonga, Ellice, Gilbert, and Marshall Islands, the Carolines and Southern Ladrones, and the Maldives, in the Indian Ocean.

Recognising that Darwin's theory did not explain the conditions observed, my reports were limited to descriptions of the different types of Coral reefs and of the causes to which they probably owed their formation, and no attempt was made to establish any independent general theory.

Beginning with the Barrier Reefs, we find that those of Fiji, the Hawaiian Islands, and the West Indies usually flank volcanic islands and are underlaid by volcanic rocks. Those of New Caledonia,

Australia, Florida, Honduras, and the Bahamas, are underlaid by outliers of the adjoining land masses, which crop out as islands and islets on the very outer edge of the Barrier Reefs. Some of the Barrier Reefs of the Society Islands, of Fiji, and of the Carolines, show that the wide and deep lagoons, separating them from the land mass, have been formed by erosion, from a broad fringing reef flat. Encircling reefs, such as characterise especially the Society Islands, hold to their central island or islands the same relation which a Barrier Reef holds to the adjoining land mass. Denudation and submarine erosion fully account for the formation of platforms upon which coral reef and other limestone organisms may build, either barrier or encircling reefs, or even atolls, rising upon a volcanic base, of which the central mass may have disappeared, as in Fiji, the Society and Caroline Islands.

We may next take the type of elevated islands of the Paumotus, the Fiji, the Gilbert, and the Ladrones, many composed only of tertiary limestones, others partly of limestone, and partly volcanic. We can follow the changes from an elevated island, like Niue, or Makatea in the Paumotus, to an island like Niau, through a stage like Rangiroa to that of the great majority of the atolls in the Paumotus. The reef-flats and outer reefs flanking elevated islands, hold peculiar relation to them, they are partly those of Barrier Reef and partly of Fringing Reef. We may also trace the passage of elevated plateaux like Tonga, Guam, and islands in Fiji, partly volcanic and partly limestone, to atolls where only a small islet or a larger island of either limestone or volcanic rock is left to indicate its origin. Atolls may also be formed upon the denuded rim of a volcanic crater, as at Totoya and Thombia in Fiji, as well as in some of the volcanoes east of Tonga.

In the Ellice and Marshall group and the Line Islands, are a number of atolls, the underlying base of which is not known, and where we can only follow the formation of the land rim of the atoll, as far as it is due to the agency of the trades or of the monsoons in constantly shifting the superficial material (prepared by boring organisms) which goes to form its rim. Many of the atolls in the Pacific are merely shallow sinks, formed by high sandbanks, thrown up around a central area.

Throughout the Pacific, the Indian Ocean, and the West Indies the most positive evidence exists of a moderate, recent elevation of the coral reefs. This is shown by the bosses, pinnacles, and undermined masses of modern or tertiary limestone left to attest it. The existence of honeycombed pinnacles of limestone within the lagoons of atolls, as shoals, islands, or islets, shows the extent of the solvent action of the sea upon land areas, having formerly a greater extension than at the present day. Signs of this solvent action are to be seen everywhere among coral reefs. Atmospheric denudation has played an

important part in reducing elevated limestone islands to the level of the sea, by riddling them with caverns and by forming extensive sinks, often taken to be elevated lagoons.

Closed atolls can hardly be said to exist; Niau in the Paumotus is the nearest approach to one, yet its shallow lagoon is fed by the sea through its porous ring. Sea water may pass freely into a lagoon at low tide over extensive shallow reef flats where there are no boat passages. The land area of an atoll is relatively small compared to that of the half-submerged reef flats. This is specially the case in the Marshall Islands and the Maldives where land areas are reduced to a minimum.

The Maldivian plateau with its thousands of small atolls, rings, or lagoon reefs, rising from a depth varying from 20 to 30 fathoms, is overwhelming testimony that atolls may rise from a plateau of suitable depth, wherever and however it may have been formed and whatever may be its geological structure. On the Yucatan plateau similar conditions exist regarding the formation of atolls, only on a most limited scale.

The great coral reef regions are within the limits of the trades and monsoons and areas of elevation, with the exception of the Ellice and Marshall Islands and some of the Line islands. The extent of the elevation is shown by the terraces of the elevated islands of the Paumotus, Fiji, Tonga, Ladrones, Gilbert, and West Indies, or by the lines of cliff caverns indicating levels of marine erosion.

In the regions I have examined the modern reef rock is of very moderate thickness, within the limits of depth at which reef builders begin to grow, and within which the land rims of atolls or of Barrier Reefs are affected by mechanical causes. This does not affect the existence of solitary deep-sea corals, of extensive growths of Oculina or Lophohelia at great depths, or in any way challenge the formation of thick beds of coralliferous limestone during periods of subsidence.

The Marquesas, Galapagos, and a few islands in the Society and West Indies have no corals, although they are within the limits of coral areas. Their absence is due to the steepness of their shores and to the absence or crumbling nature of their submarine platforms. Coral reefs also cannot grow off the steep cliff faces of elevated, coralliferous limestone islands.

Corals take their fullest development on the sea faces of reefs; they grow sparingly in lagoons where coralline algæ grow most luxuriantly. Nullipores and corallines form an important part of the reef-building material.